Systems and Software

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Integrity ★ Service ★ Excellence

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2013 AFOSR SPRING REVIEW

NAME: Systems and Software

BRIEF DESCRIPTION OF PORTFOLIO:

- **Enable quantifiable performance evaluation of critical systems**
- **Manage environments in order to preserve vital mission functions**
- **Comprehensively understand distributed effects in large infrastructures to predict global system failures**

LIST SUB-AREAS IN PORTFOLIO:

- **Composeable Dynamic Models**
- **Formal Analysis and Verification**
- **Assessment/Repair of Failure**

Current Program Scope

- Composeable Dynamic Models
  - New programming languages or language constructs reduce errors at run-time
  - Domain-specific languages enhance capabilities for code generation
- Dynamic Formal Analysis and Verification
  - Verification of system properties based on formal specifications
- Assessment/Repair of Failure
  - Abstract models of systems and their interactions facilitate automated generation of code

Scalable Model Checking

C. Tinelli U Iowa, C. Barret, NYU

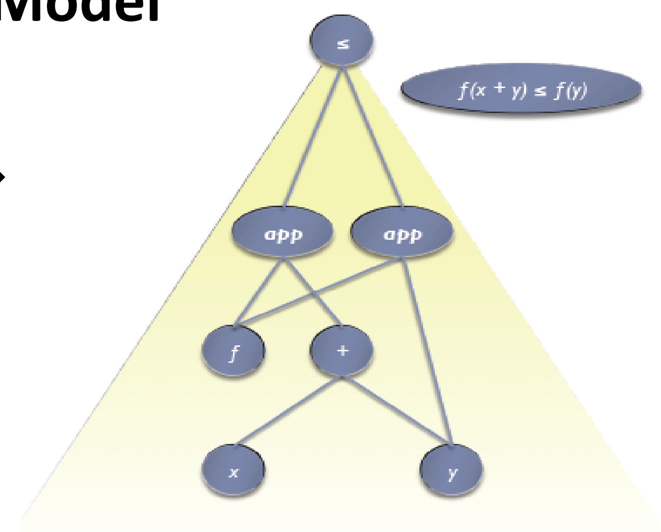
Approach: Formal verification suffers from state space explosion. Compactly represent logical symbols in scalable nested satisfiability modulo theory (SMT)

Payoff: More scalable verification to handle large heterogeneous systems

Compact SMT Language

- Valid:
  - satisfied by all states in Q
- Inductive:
  - $I(s_0) \models P(s_0)$,
  - $P(s_n), T(s_n, s_{n+1}) \models P(s_{n+1})$
- k-inductive:
  - $I(s_0), T(s_0, s_1), \ldots, T(s_{k-1}, s_k) \models P(s_0), \ldots, P(s_k)$,
  - $T(s_n, s_{n+1}), \ldots, T(s_{n+k}, s_{n+k+1}), P(s_n), \ldots, P(s_{n+k}) \models P(s_{n+k+1})$
- Invariant:
  - satisfied by all reachable states of S

Improved Lower Dimensional Model



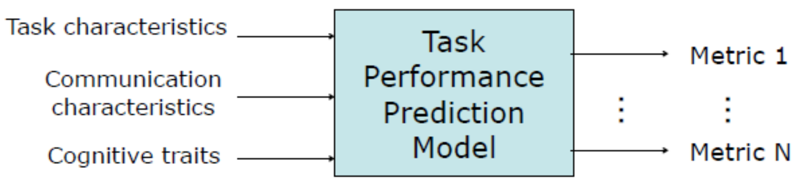
Stochastic Methods for Dynamic Scalable System Verification

Mark Campbell, Cornell

Approach: Heterogeneous and uncertain states characterize system performance across multiple levels of software. Using stochastic models can enable robust characterization for system performance verification

Payoff: Computationally tractable ways of system performance verification at multiple layers of software including human interaction

System Performance Model



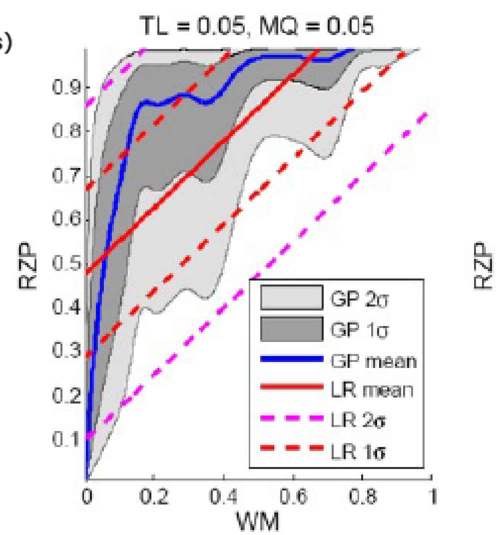
System Performance Model

TL = Task load (# enemies)

MQ =Message quality (% relevant messages)

WM =Working memory (OSPAN)

= Gaussian noise (fixed std dev)



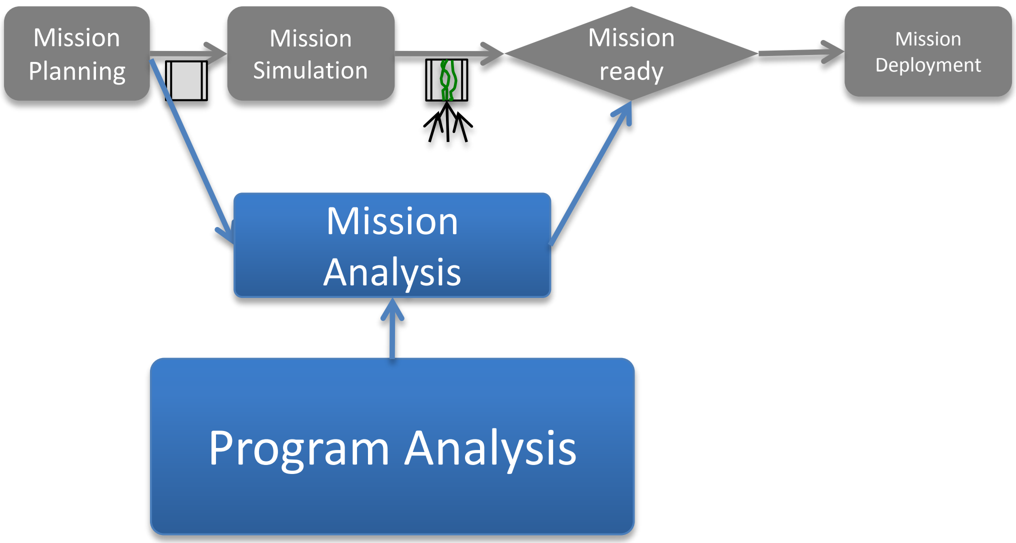
Mission Verification

Elbaum, Dwyer U. Neb., Rosenblum

Approach: **Develop a language to represent mission scenarios tied to integrated distributed software architecture.**

Payoff: **Verify global mission properties as function of lower level software constructs for quantifiable fault tolerance in achieving mission objectives**

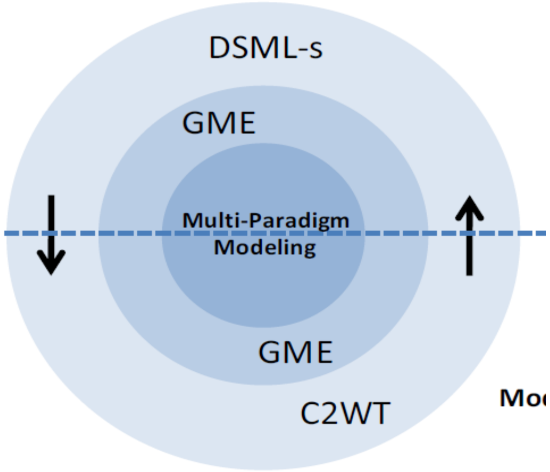
Mission Analysis Language Architecture



Systems and Software

AFRL Tech Directorate Interest/Coordination

- Information Directorate
  - Systems and Software Producibility
  - Multi-core Computing
- Air Vehicles
  - Flight-critical systems and software
  - Mixed-criticality architectures
- Human Effectiveness
  - Modeling of human-machine systems
  - Meta-information portrayal STTR
  - Robust Decision Making
  - Large Scale Cognitive Modeling/C2WT



Increased Scale/Integration via DSMLs Anchored in DEVS (Douglass, 711th HPW/RH)

DEVS (*discrete event system specification*)
- Formal rigor
- Model reusability
- Interoperability

A discrete event system specification (DEVS) is a mathematical structure (7-tuple)

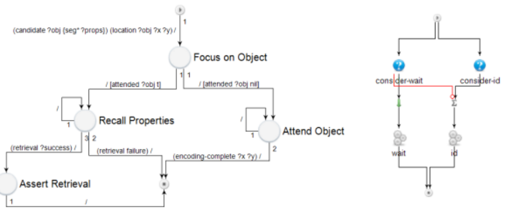
$$M = \langle X, S, Y, \delta_{int}, \delta_{ext}, \lambda, ta \rangle$$

where

X	*is the set of input values*
S	*is a set of states*
Y	*is the set of output values*
$\delta_{int} : S \rightarrow S$	*is the internal transition function*
$\delta_{ext} : Q \times X \rightarrow S$	*is the external transition function*
$\lambda : S \rightarrow Y$	*is the output function*
$ta : S \rightarrow R_{0,\infty}$	*is the time advance function*

Navigator

Plans routes from targets to targets under constraints



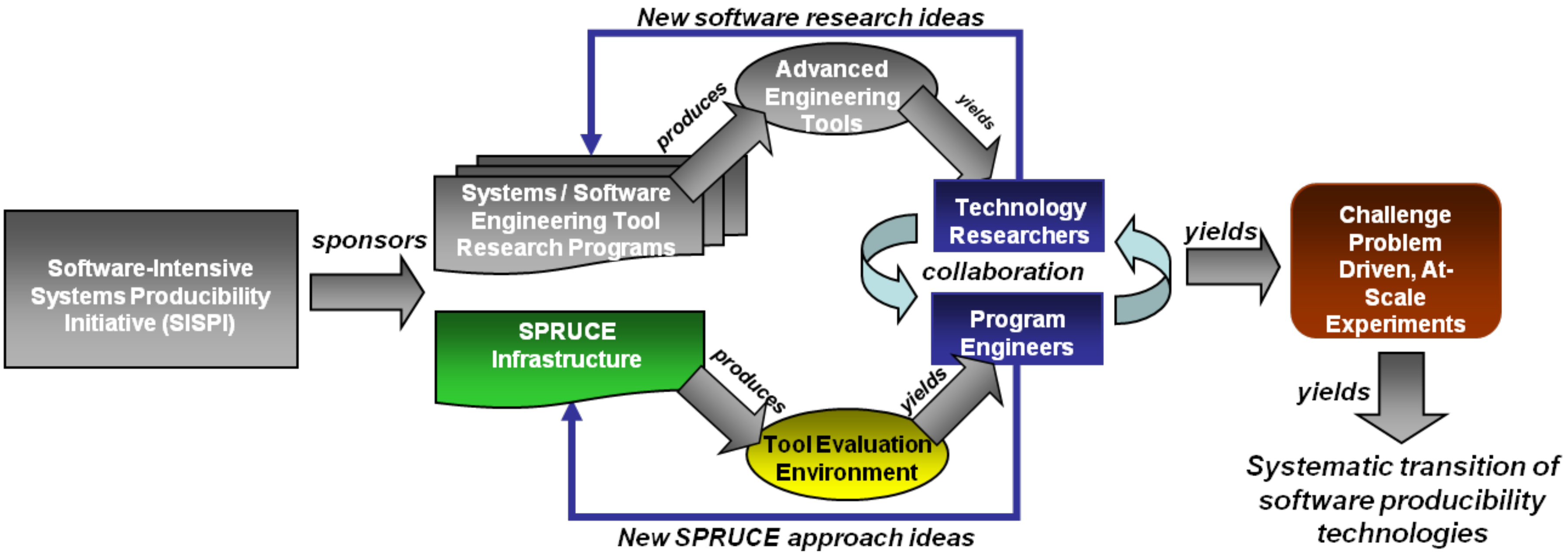
Domain-Specific Languages
- Tailored for cognitive modeling
- Semantically anchored in DEVS

High-Performance Computing
- Scalable simulation infrastructure
- Exploiting 25 years of DEV

Drager/RI

Approach: **Use parallel processing resources and network infrastructure as means of emulating and detecting system faults**

Payoff: **Far fewer defects and more detailed assessment of integrated system performance**



Collaborations at AFOSR

- **Information Operations and Security**
  - Fundamental software constructs for system security
- **Information Fusion**
  - Signal and sensor processing for integration of large data into systems architectures
- ***Complex Networks***
  - Mathematical and statistical methods for network and networked systems
- ***Foundations of Information Systems***
  - Measurement and statistical verification for software, network, and hardware
- **Computational Mathematics**
  - Methods of computational modeling of large complex physical processes
- **Dynamic Data Driven Applications Systems**
  - Strategies for real time feedback of data into distributed computational processes
- **Optimization and Discrete Mathematics**
  - Optimization strategies and algorithms for discrete computational processes
- ***Dynamics and Control***
  - Dynamical systems theory for assessment of performance of control architectures

Systems and Software

Agency Interaction & Funding Agencies

Agency Interactions:

- OSTP/NITRD Coordinating Group
  - High Confidence Systems and Software (HCSS)
- ASDR&E
  - Software Producibility Initiative
- NSF
  - Cyber Physical Systems
- NASA
  - V&V of Flight Critical Systems
  - Ames Research Laboratory

Other Funding Agencies

- ARO
- ONR
- DARPA